

## **Orthopedic Rod System**

### **RELATED APPLICATIONS**

This application is related to, and claims priority from, the following earlier-filed U.S. Provisional Patent Applications : (Serial No.s) 60/ 423,168 (filed 04 November 2002) ; 60/ 479,822 (filed 20 June 2003). Each is incorporated herein by reference.

### **TECHNICAL FIELD**

The present invention relates to orthopedic implantable devices, related systems, and associated methods of use and, more particularly, to a pedicle screw and rod system and associated method for joining two or more bone segments, such as vertebrae.

### **BACKGROUND OF THE INVENTION**

Pedicle screw systems used for fastening spinal rod systems to the pedicle region of two or more vertebral bodies exist in a variety of forms. Successive designs have strived to attain optimal levels of performance, costs, and ease of use. Some known pedicle screw systems provide a locking cap that is threadingly received into a holding sleeve. To lock the pedicle screw relative to the rod the cap is placed into the sleeve (the rod positioned therebetween), and the cap is tightened. This task is difficult since the surgeon must manipulate and tighten the cap while holding the pedicle screw and rod at a particular desired angle. Associated problems are difficulty of installation and cross-threading.

Alternative designs include cams or circular ramps to reduce the number of turns required to lock the cap. Such designs require costly and precise tolerances and are difficult to use during surgery.

### **OBJECTS AND SUMMARY OF THE INVENTION**

It is an object of the present invention to provide pedicle screw and rod system that overcomes the above-described shortcomings associated with prior, known designs.

These and other objects are described below or inherent with respect to the present invention.

In one aspect of the present invention, a tulip-shaped rod-receiving member is provided with a transverse slot accessible from the top of the tulip member for placing the rod therein until the rod seats. A locking assembly includes a cap having transversely aligned wings that are passed through the slot and then, as the cap is rotated, positioned into dove-tail like grooves that prevent the cap from being backed out. A set screw positioned through the cap is tightened against the rod applying downward force thereto while transmitting upward force to the tulip via the dovetail groove. The groove has angled sides that cooperate with angled sides of the cap wings so that as force is increased, the angle sides slide relative to each other in a manner that applies closing force to the tulip, rather than spreading force.

In another embodiment of the present invention, a tulip-shaped receiving member with a slot for receiving a rod has at least two inverted shoulders that have downwardly-facing contact surfaces that incline upwardly in a direction radially outwardly from a center axis of the tulip. A locking cap is provided having at least two shoulders that have upwardly-facing contact surfaces that incline upwardly in a direction radially outwardly from a center axis of the cap, so that the respective inclined surfaces of the cap and the tulip matingly engage. Thus, when a tightening screw is advanced through a central opening in the cap to exert pressure on a rod positioned through the tulip-slot, the reaction force transmitted to the screw is transferred to the inclined surfaces causing the walls of the tulip to be biased radially inwardly as the rod is locked increasingly.

Another aspect of the present invention, specifically directed to the embodiments described below relating to multi-axis systems, provides that due to the novel design of a seated bone screw, maximum alignment of locking forces can be achieved with minimal sizing of a screw head.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a pedicle screw and rod system according to a preferred embodiment of the present invention.

FIG. 2 is a side, cross-sectional view of the pedicle screw and rod system according to FIG. 1.

FIG.3 is a partial, cross-sectional view of the pedicle screw and rod system according to FIG. 1.

FIG.4 is a partial, cross-sectional view of the pedicle screw and rod system according to FIG. 1, shown in the un-locked position and viewed at 90 degrees with respect to FIG.3.

FIG.5 is a partial, cross-sectional view of the pedicle screw and rod system according to FIG. 1, shown in the locked position and viewed at 90 degrees with respect to FIG.3.

FIG.6 is a schematic, perspective view of a component of the pedicle screw and rod system according to FIG. 1, having exaggerated dimensions for illustrative purposes.

FIG. 7 is a cross-sectional view of a pedicle screw and rod system according to a second embodiment of the present invention.

FIG. 8 is a schematic, cross-sectional view of a pedicle screw and rod system according to a third embodiment of the present invention.

FIG. 9 is a schematic, cross-sectional view of a pedicle screw and rod system according to the third embodiment of the present invention.

Fig. 10 is a schematic, cross-sectional view of a prior art pedicle screw and rod system.

Fig. 11 is a front, cross-sectional view of a pedicle screw and rod system according to the third embodiment of the present invention.

Fig.s 12A and 12B are partial, side, cross-sectional views of a pedicle screw and rod system according to Fig. 11.

Fig. 13 is a perspective view of a pedicle screw and rod system according to Fig. 11.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Fig.s 1-3, a pedicle screw (10) according to the present invention includes a first end (12) adapted to be driven into bone, a threaded intermediate portion (14), and a head (16) having a semicircular profile. The screw (10) is positioned through a central opening (18) in a rod-receiving cup (20). The cup (20) has a lower, conical

interior surface (22) that the head (16) pivotally rests in. The head (16) also includes a dome top (24) and a driver-engaging socket (26).

The cup (20) has two opposed slots (28) forming a yoke through which a rod (30) is received. A lower surface (36) of a seat element (32) rests in slideable contact with the dome top (24) of the screw head (16). The upper surface (34) of the seat element (32) contacts the rod (30). An upper cap (38) is received in the upper end of the cup (20) above the rod (30). A locking threaded screw (40) having a tool engaging socket (44) is tightened through a central, threaded opening (42) in the cap (38) so that the locking screw (40) contacts the rod (30).

As the locking screw (40) is tightened, it is driven against the rod, thereby causing upward displacement of the cap (38). Because the cap (38) is constrained against upward movement by the cup (20), and the rod (30) and seat element (32) are constrained against downward movement by the screw head (16), which bottoms out against the inner surface (22) of the cup (20), these components are all locked relative to each other by turning of the locking screw (40). Fig. 4 illustrates an unlocked condition, and Fig. 5 illustrates a locked condition. These modes facilitate angular selection and locking of the pedicle screw (10).

The cap (38) is constrained against upward movement by the cup (20) due to its upwardly tapering ramps (46), which correspond to an inverted, matching inner wall (48) of the cup (20) interior, as shown in Figs 4-5. The cap (38) has opposed, radially extending wings (50, 52) with top arms (54, 56) having downwardly-extending ends (58, 60) and ramps (46).

In order to more clearly illustrate the locking features of the cap (38), a schematic illustration of the cap (38) is shown in Fig. 6 having exaggerated dimensions. The wings (50, 52) can be aligned within the yoke formed by the slots (28), and then turned ninety degrees to position the ramps (46) into engagement with the cup inner wall (48). The downwardly-extending ends (58, 60) of the arms (54, 56) engage the outside surface of the cap (38) to prevent radially outward deflection or deformation of the cup (20) as the

locking screw (40) is advanced against the rod (30) causing the cap (38) to be biased upwardly against the tapered inner surface (48) of the cup (20).

This design allows loose retention of the components relative to the rod so a surgeon can easily make adjustments. It also enables superior performance without the need for costly high tolerancing.

A second embodiment of the present invention, shown in Fig. 7, is directed to fixed axis pedicle screw (100) having a shaft (102), such as a threaded shaft, and a head (104) integrally formed. The head (104) has a slotted opening (106) similar to that described above with respect to the first embodiment of the present invention designed to cooperate with a cap member (108) having wings (110) with angled surfaces (112) of the type described with respect to the first embodiment. A set screw (114) is designed to apply downward force to a rod (116) as described above with respect to the first embodiment. The wings (110) are passed through the slot (116) and then, as the cap (108) is rotated, positioned into dove-tail like grooves (118) that prevent the cap from being backed out. A set screw (114) positioned through the cap (108) is tightened against the rod (116) applying downward force thereto while transmitting upward force to the tulip via the dovetail groove (118). The groove (118) has angled sides (120) that cooperate with angled sides (112) of the cap wings so that as force is increased, the angle sides (120, 112) slide relative to each other in a manner that applies closing force to the tulip, rather than spreading force.

A third embodiment of the present invention as shown schematically in Fig. 8 is essentially similar to the first embodiment described herein, except that it utilizes a seat sleeve (200) for seating the screw head (202) relative to the cup (204) or tulip. In this embodiment, the use of the seat sleeve (200) enables a smaller screw head (202) to be used, while enabling a wide range of angular positioning of the screw (206) relative to the cup (204) that would otherwise be unattainable without the seat sleeve (200). The sleeve (200) retains the screw (206) in an opening of the cup (204) that the screw (206) would otherwise fall through. As illustrated with respect to Figs 9 - 10, the third embodiment of the present invention, represented schematically in Fig. 9, enables the center (210) of the

screw head (214) to remain vertically aligned with the center (212) of the rod (208). Referring to the schematic of the PRIOR ART in Fig. 10, the size of the screw head (300) relative to the cup (302) and its opening causes the center (304) of the head (300) to move out of vertical alignment with the center (306) of the rod by a distance "a". The superior alignment of the centers of the rod and the screw head achieved by the present invention distributes loads more equally within the cup, on the supporting structures, through the rod, and finally to the ramped surfaces of the cup dovetail groove and the cap angled surfaces. This relatively even stress distribution and efficient use of existing forces internal to the system provide superior performance and locking of the screw relative to the rod assembly.

With references to Figs 11-13, the third embodiment schematically represented in Figs 8 - 9 is illustrated by way of example in a pedicle screw and rod system (400). A pedicle screw (402) having a generally hemispherical head (404) suspended in a tulip (406) having a slot (408) for receiving an orthopedic rod such as a spinal rod (410). The tulip (406) has two sidewalls (412, 414) formed adjacent to the slot (408). Each sidewall (412, 414) has an inverted shoulder (416, 418) formed on the inner side of the sidewall. The inverted shoulders (416, 418) are inclined upwardly in a radially outward direction as shown. A cap (420) having two shoulders (422, 424), each being inclined upwardly in a radially outward direction as shown, is adapted to be positioned in the tulip (406) as shown. For optimal performance, it is preferable that the incline of the inverted shoulders (416, 418) be greater, or steeper, than the incline of the cap shoulders (422, 424), though they could also be approximately equal or less.

In use, the pedicle screw (402) is driven into bone while it is seated on a seat ring (426) that rests in a conically-tapering bottom opening (428) of the tulip (406). Because the ring (426) is a spacer between the screw head (404) and the tapered contact surface (430) inside the tulip (406), it enables a smaller profiled head (404) and screw thickness relative to the tulip opening (428), thus facilitating a wide range of angular adjustment of the pedicle screw (402) relative to the tulip (406). This is a significant improvement over known designs.

After the pedicle screw (402) is driven into the bone, a spacer cap (432) having a contoured lower contact surface (434) for engaging the screw head (404) and an upper contact surface (436) for engaging the rod (410) is positioned as shown in Fig. 11. The rod (410) is positioned, via the slot (408) to the position shown in Fig. 11, and the cap (420) is placed into the top of the tulip (406). The tulip (406) and pedicle screw (402) are manipulated to a relative angular orientation that is desired and held in such a position while the tightening screw (438) in the center of the cap (420) is advanced toward the rod (410). The tightening screw (438) is preferably threaded on its exterior and adapted to mate with threads on the interior of a hole in the center of the cap (420), as shown in Fig. 11. As the tightening screw (438) is advanced into contact with the rod (410) and further advanced, reaction forces transmitted from the rod (410) to the screw (438) are transmitted to the inclined shoulders (416, 418) of the sidewalls and the shoulders (422, 424) of the cap (420). The action of the inclined surfaces of the tulip shoulders (416, 418) and the cap shoulders (422, 424) being drawn against each other causes the sidewalls (412, 414) to be drawn radially inwardly, more tightly as the rod (410) is more tightly secured by the tightening screw (438). The tightening screw (428) is provided with a driving engagement feature (440) for applying turning torque. Because of the selected radius dimension of the screw head (404) and its point of suspension relative to the tulip (406), pivotal adjustment and locking of the pedicle screw (402) relative to the tulip (406) will always result in the force of the tightening screw (438) being directed along a line that intersects the center of the screw head (404).

While the present invention has been described herein, various modification may be made without departing from the scope of the invention.